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MONITORING OF BOREHOLE DEFORMATION AT NIOBEC MINE, A PROGRESS REPORT

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Canadian Mine Technology Laboratory

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MONITORING OF BOREHOLE DEFORMATION AT NIOBEC MINE, A PROGRESS REPORT

by

G. Herget* and F. Kapeller**

SUMMARY

In cooperation with the Centre de Recherches Minérales, Québec, the Mining Research Laboratory of EMR Canada installed seven MRL strain rings in Niobec Mine, on an experimental basis, into T-8-203-13 pillar and C-8-203-15 stope at the 850 level. The rings have provided reliable readings since the time of their installation on the effect of mining on stress redistribution. Maximum deformation has been measured at site 2, (November 27, 1986) in horizontal direction as -0.0598 mm and in vertical direction as 0.0106 mm which indicates a loss of stress of 731 psi (5 MPa) in horizontal direction and a loss of 121 psi (0.8 MPa) in vertical direction. More significant changes are expected with additional mining.

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KEYWORDS: Borehole deformation, strain monitoring, induced stresses, in situ deformation.

SURVEILLANCE DE LA DÉFORMATION DES TROUS DE SONDE À LA MINE NIOBEC
RAPPORT D'ACTIVITÉ

par

G. Herget* et F. Kapeller**

SOMMAIRE

Les Laboratoires de recherche minière d'EMR Canada, en collaboration avec le Centre de Recherches Minérales du Québec, ont installé à titre d'expérience sept anneaux de déformation des LRM dans le pilier T-8-203-13 et dans la chambre C-8-203-15 au niveau 850 de la Mine Niobec. Depuis leur installation, les anneaux ont permis de déterminer avec fiabilité les effets de l'exploitation minière sur la répartition des contraintes. La déformation maximale à l'emplacement 2, mesurée le 27 novembre 1986, était de -0,0598 mm dans la direction horizontale et de 0,0106 mm dans la direction verticale, ce qui indique des pertes de tension de 731 psi (5 MPa) sur le plan horizontal et de 121 psi (0,8 MPa) sur le plan vertical. On prévoit qu'en poursuivant l'exploitation minière, des changements plus importants seront notés.

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MOTS-CLÉS déformation de trou de sonde, surveillance des contraintes, contraintes provoquées, déformation in situ.

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INTRODUCTION

Prediction of ground reaction and possible failure during mining is still an imperfect procedure even with the ability of numerical tools, strength determinations and ground stress determinations. Therefore, it is necessary to check predictions of ground behaviour by monitoring. Elastic responses in hard-rock, however, produce very small deformations which are difficult to monitor on a long term basis. For this reason a new instrument was developed at the Mining Research Laboratories which allows monitoring of diametrical strain down to 5 micro-strain on a long term basis. This report describes preliminary results of monitoring the ground reaction to mining using the device at Niobec Mine in cooperation with the Centre de Recherches Minérales. The mine produces rare earths from a carbonatite deposit near St. Honoré, Québec.

MRL STRAIN RING

The MRL strain rings are relatively large, hardened steel rings which are set in boreholes with steel wedges and which use vibrating wires to monitor diameter changes. The vibrating wire proving rings were designed at the Mining Research Laboratories of CANMET, EMR and were custom built by a subcontractor to fit into a 153 mm diameter hole. A photograph of the device is given in Fig. 1. A total of six rings were built by a subcontractor. One additional ring, the installation equipment and the wedge system, were supplied by CANMET Mining Research Laboratories. The rings are capable of providing long term monitoring of borehole deformation.

Figures 2 to 7 show the calibration curves obtained during loading of the stress rings with the wedges in place in a Tinuis-Olsen testing machine. Readings were obtained for frequency change against load on rings and deformation. In mid range the rings have similar calibration factors:

Ring	Pre stress (kN/Hz)	Range (Hz)	Range (kN)	Range (mm)	kN/Hz	$(10^{-4}$ mm)/Hz
		445	32			
1	18/200	1150-705	18-50	0.251	0.0719	5.64
		470	33			
2	17/200	1150-680	17-50	0.201	0.0702	4.28
		345	30			
3	20/200	1150-805	20-50	0.157	0.0869	4.55
		447	33			
4	17/200	1150-703	17-50	0.203	0.0738	4.54
		445	33			
5	17/200	1150-705	17-50	0.157	0.0742	3.53
		455	33.5			
6	16.5/200	1150-695	16.5-50	0.218	0.0736	4.79

The wedges used with the above cells have a load bearing area of 3 $in.^2$ (6 in. x 0.5 in.) At 50 kN the pressure on the wedges = $\frac{11241}{3}$ = 3747 psi. This pressure is permissible for an in situ rock strength of more than 10,000 psi.

Vibrating wires are very sensitive to temperature variations. Commercial literature shows a coefficient of thermal expansion of 10.8 ppm/°C for piano wire. For a temperature increase of 10°C, a change in elongation of 108 ppm results. This results in an elongation, $\Delta\ell$, for a 4 in. wire of:

$$\Delta\ell = 0.000108 \times 4 \text{ in.} = 0.000432 \text{ in. } (0.0109 \text{ mm})$$

This would result in a frequency change of about 25 Hz. Therefore, the stress rings were fitted with a thermistor which can be easily read by an ohn-meter. The calibration is given in Fig. 8.

FIELD INSTALLATION

Monitoring sites were located in pillar T-213-13 and in the overcut of stope C-203-15 at the 850 level. The design width of both the pillar and the stope is 24.2 m. Prior to their

development the MRL rings were installed in drillholes along the centreline of T-213-13 pillar and along the centreline of the narrow pillars in the overcut. The location of the rings is shown in Fig. 9. The installation dates and the measuring orientations are given below:

Site	Ring	Depth (m)	Date	Initial reading (Hz)
1	6,V	6.39	16.7.86	1081
1	EhR11,H	4.60	7.9.86	1520
2	5,V	7.60	17.7.86	1105
2	1,H	7.30	17.7.86	1113
2	3,H	6.4	7.9.86	1100
3	2,V	7.30	16.7.86	1207
3	4,V	7.15	16.7.86	1265

While initial ring readings were obtained by MRL staff, subsequent on site readings were made by D. Labrie, Centre de Recherches Minérales, Québec, in cooperation with mine staff. The mine also provided mine data such as updated mine geometry, occurences of production blasts etc. relevant to the interpretation of the strain rings.

INTERPRETATION OF READINGS

Stress determinations have been carried out on the 850 level at Niobec Mine by B. Arjang of the Elliot Lake Mining Research Laboratory in May 1986, they yielded the following results on the basis of the rock having an elastic modulus of 74.5 GPa and a Poisson's ratio of 0.26:

σ_1 = 25.3 MPa, 064/-12
σ_2 = 15.4 MPa, 160/-18
σ_3 = 8.9 MPa, 305/-69

The horizontal stress components were: E-W = 22 MPa, and N-S = 17 MPa; and the vertical stress component was 10.6 MPa. The average horizontal stress at the 850 level was 20 MPa.

The drill level (overcut) for the C-203-15 stope was planned to have two 4.9 m pillars (W_p) with rooms 4 m and 6.4 m wide (W_e) parallel to pillar T-213-13 as shown in Fig. 9. Prior to production mining in T-203-13 stope and development of the overcut, MRL rings were installed in parallel drillholes. Readings and mining geometry were compiled by D. Labrie, in December 1986.

Given the in situ ground stress, subsequent drillhole deformations with mining can be calculated. With the ground subjected to an average horizontal stress of 20 MPa and a vertical stress of 10.6 MPa, the full excavation of the drill drift would reduce the horizontal stress in the pillars where the rings were installed to approximately zero and increase their vertical stress in relation to the width of the rooms supported by the pillar on both sides. The stress changes to be expected are as follows, based on tributary area:

$$\Delta\sigma_H = \sigma_{pH} - \sigma_H = 0 \text{ MPa} - 20 \text{ MPa} = -20 \text{ MPa (relaxation)}$$

$$\Delta\sigma_V = \sigma_{pV} - \sigma_V = \sigma_{pV} - 10.6 \text{ MPa}$$

$$\sigma_{pV} = \left(1 + \frac{W_e}{W_p}\right) \sigma_V$$

$$W_e = (6.4 \text{ m} + 4 \text{ m})/2$$

$$W_p = 4.9 \text{ m}$$

$$\sigma_{pV} = (1 + 5.1/4.9) \times 10.6 \text{ MPa} - 21.2 \text{ MPa}$$

$$\Delta\sigma_V = 21.2 - 10.6 \text{ MPa} = 10.6 \text{ MPa (compression)}$$

Based on the stress distribution for a circular hole in an infinite elastic medium, Kirsch equation and Hooke's law, the radial displacements (U) and tangential displacement (V) are identified as follows for a radius (r) and elastic modulus (E):

$$U = r\,[\sigma_x + \sigma_y + 2(\sigma_x - \sigma_y)\cos 2\theta]/E$$

$$V = 2r\,(\sigma_x + \sigma_y)\sin\theta/E$$

with θ is counted anticlockwise from x.

For the monitoring at Niobec mine only horizontal and vertical radial displacements are of interest. Using the following data in the former equation horizontal and vertical deformations at the test site at full development can be determined:

$r = 0.153\ M/2$
$\sigma_x = -20$ MPa
$\sigma_y = 10.6$ MPa
$\theta_H = 0$
$\theta_V = 90$
$E = 74.5$ GPa

For radial deformation in the horizontal direction (θ - 0):

$$U = \frac{153\ mm}{2x74500\ MPa}\,[-20\ MPa + 10.6\ MPA + 2(-20\ MPa - 10.6\ MPa)\ x\ 1]$$

$U = -0.0725$ mm, and

total deformation across the diameter is 2 x U = -0.145 mm (-0.005709 in.) For radial deformation in vertical direction (θ = 90):

$$U = \frac{153\ mm}{2x74500\ MPa}\,[-20\ MPa + 10.6\ MPA + 2(-20\ MPa - 10.6\ MPa)\cos 180°]$$

$$U = \frac{153 \text{ mm}}{2 \times 74500 \text{ MPa}} \times 57 \text{ MPa} = 0.0532 \text{ mm, and}$$

total deformation across the diameter is 2 x U = 0.1064 mm (0.004189 in.). These values represent approximations.

At the time of writing this report the development of the overcut had only reached the stage shown in Fig. 10. This shows that pillar and drift development was not complete by November 27, 1986. Therefore, the values of deformation realized would be well below those predicted at the end of their development. A summary of the readings obtained at Site 2 is given in Fig. 11. The following deformations were obtained:

VERTICAL DIRECTION:

Compression: 30 Hz x 3.53×10^{-4} mm (Ring 5) = 0.0106 mm
Radial deformation = 0.0106 mm/2 = 0.0053 mm.

HORIZONTAL DIRECTION:

Expansion: 106 Hz x 5.64×10^{-4} mm (Ring 1) = 0.0599 mm
Radial deformation = 0.0599 mm/2 = 0.0299 mm.

Using the Kirsch equation with θ in x-direction (horizontal) = 0 and θ in y-direction (vertical) = 90° and assuming that these directions are principal stress directions with σ_H acting in horizontal direction and σ_V acting in vertical direction, the stress changes from the above deformations can be calculated as follows:

Vertical Radial Deformation:

$$U = \frac{r}{E} [\sigma_x + \sigma_y + 2(\sigma_x - \sigma_y] \cos 2\theta, \ \theta = 90°$$

$$0.0053 \text{ mm} = \frac{r}{E} [\sigma_H + \sigma_V - 2\sigma_V] = \frac{r}{E} [\sigma_H + 3\sigma_V]$$

Horizontal Radial Deformation:

$$U = \frac{r}{E} (\sigma_x + \sigma_y + 2(\sigma_x - \sigma_y) \cos 2\theta, \theta = 0°$$

$$0.0299 \text{ mm} = \frac{r}{E} [\sigma_H + \sigma_V - 2\sigma_H - 2\sigma_V] = \frac{r}{E} [3\sigma_H + \sigma_V]$$

To isolate one of the stresses:

$$-\sigma_H + 3\sigma_V = \frac{0.0053 \text{ mm} \times E}{r}$$

$$9\sigma_H + 3\sigma_V = \frac{-0.0299 \text{ mm} \times E \times 3}{r}$$

$$8\sigma_H = \frac{E}{r} (0.0053 \text{ mm} - 0.0897 \text{ mm})$$

$$\sigma_H = \frac{10.6 \times 10^6 \text{ psi} \times (-0.0844 \text{ mm})}{76.5 \text{ mm} \times 8} = -1462 \text{ psi } (-10 \text{ MPa})$$

$$3\sigma_V = \frac{0.0053 \text{ mm} \times E}{r} + \sigma_H$$

$$\sigma_V = (734 \text{ psi} - 1462 \text{ psi})/3 = -242 \text{ psi} (-1.6 \text{ MPa})$$

At this point it can only be said that the monitoring site has lost about 1462 (10 MPa) in horizontal direction and in the vertical direction -242 psi (-1.6 MPa) which is due to the existing mining geometry. The monitoring site is still in an elastic condition and the MRL rings are performing as expected.

ACKNOWLEDGEMENTS

The authors wish to thank Niobec Mines for providing the services required to instal and monitor the strain cells. The good cooperation with the Centre de Recherches Minérales is appreciated.

REFERENCE

1. Labrie, D. "Monitoring dans le chantier C-8-203-15 et le pilier T-8-203-13"; Centre de Recherches Minérales; decenber 1986.

Read out unit

Calibration of MRL strain ring

Fig. 1 - MRL strain ring.

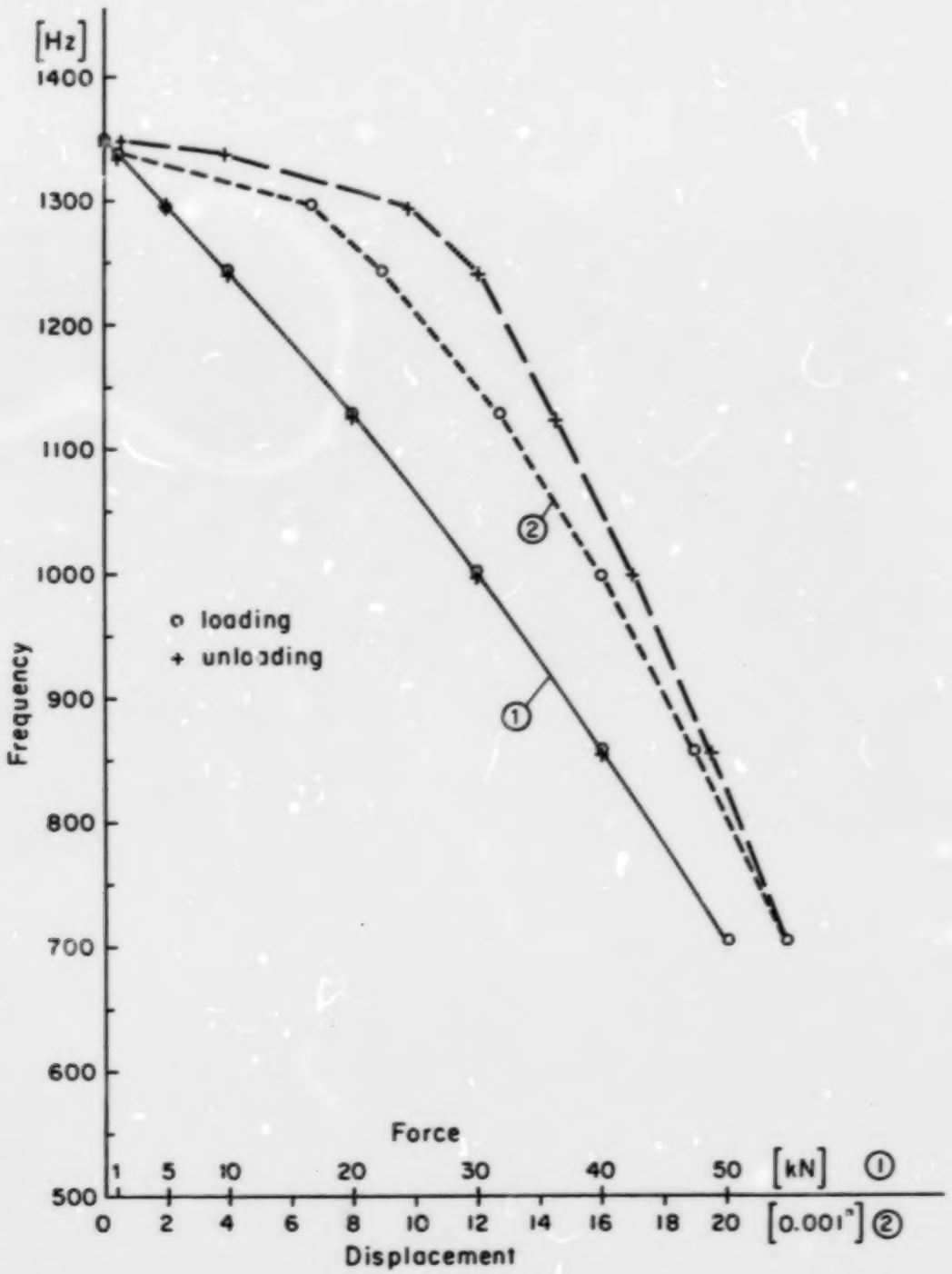

Fig. 2 - Calibration of ring 1.

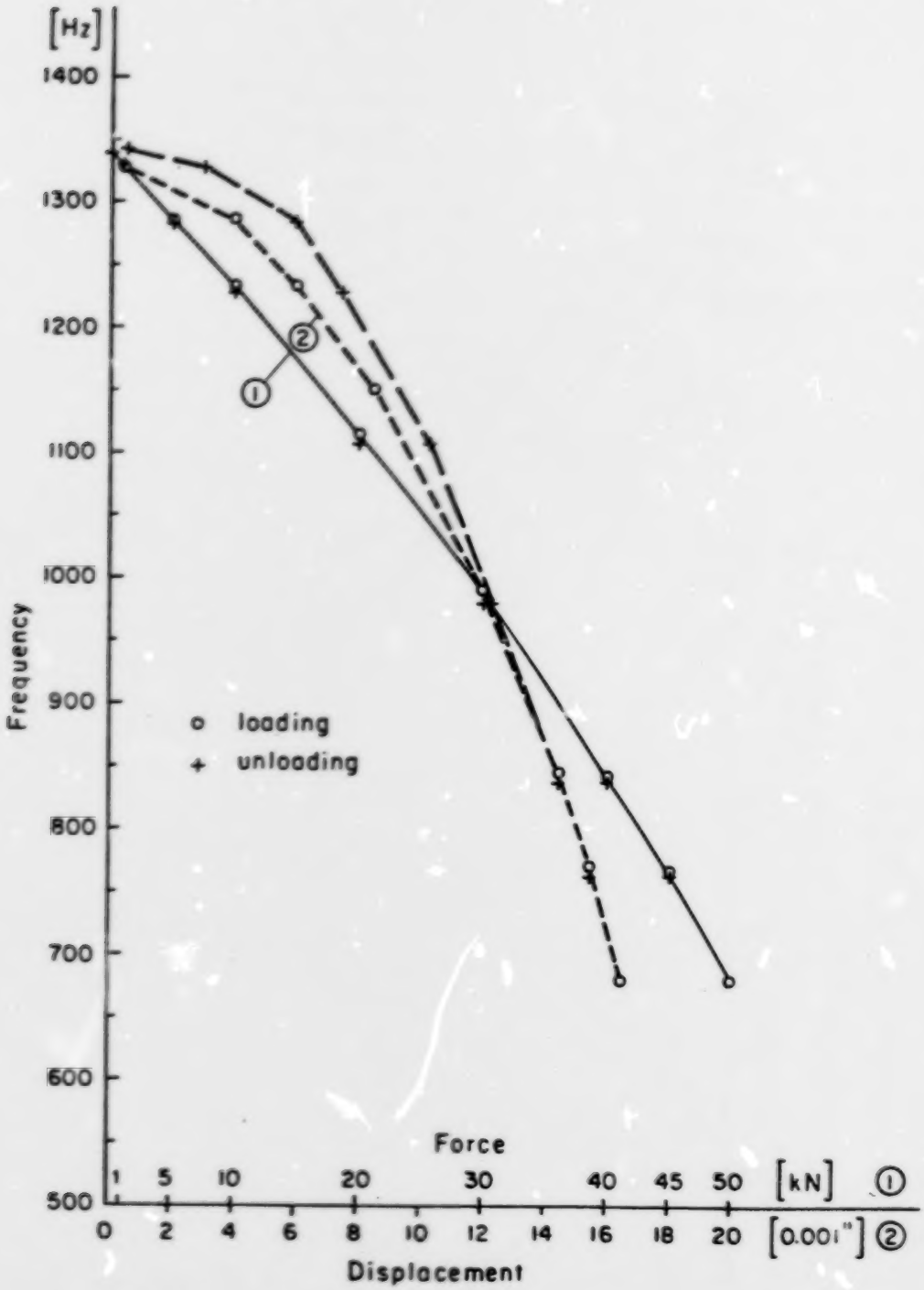

Fig. 3 - Calibration of ring 2.

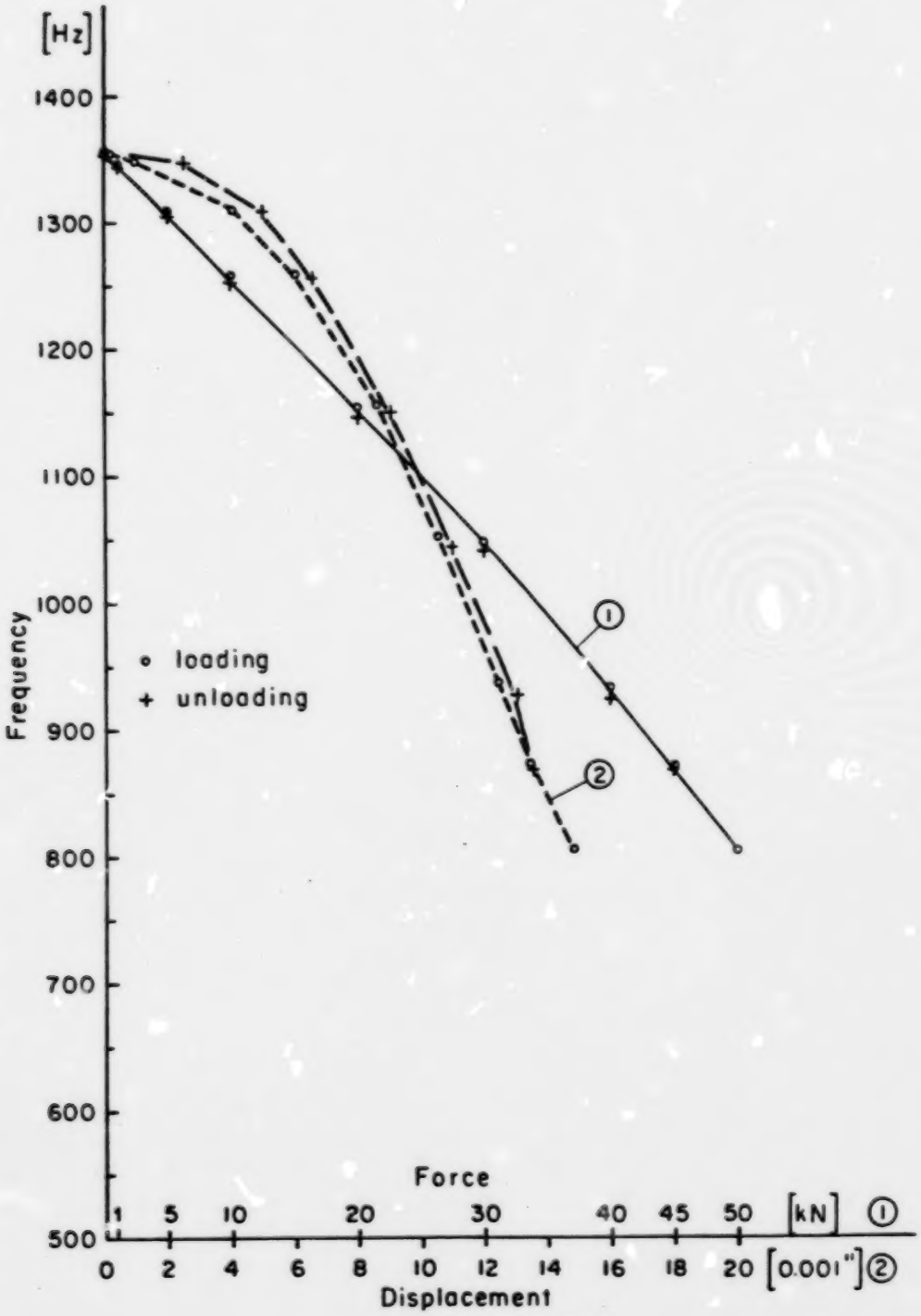

Fig. 4 - Calibration of ring 3.

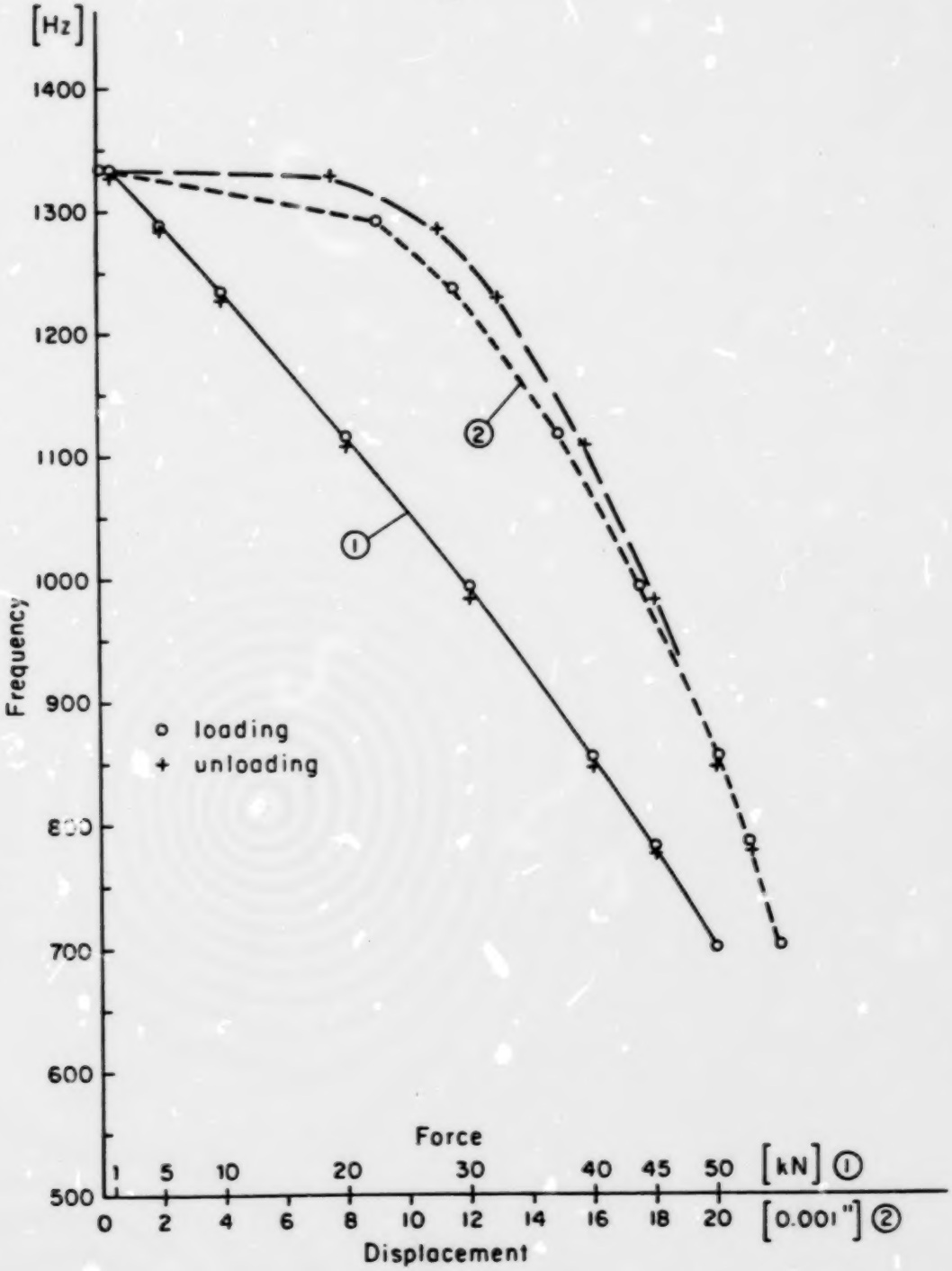

Fig. 5 - Calibration of ring 4.

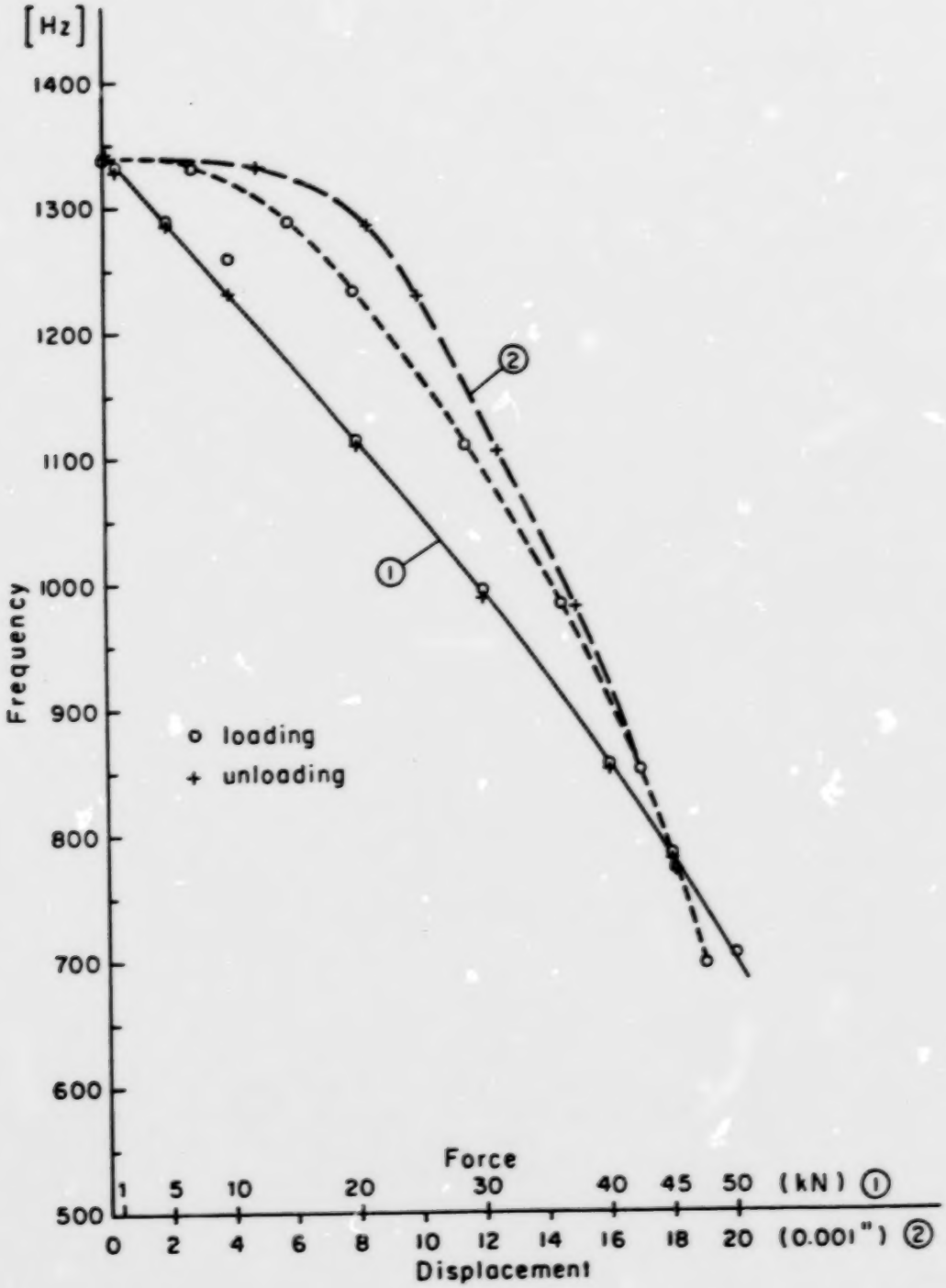

Fig. 6 - Calibration of ring 5.

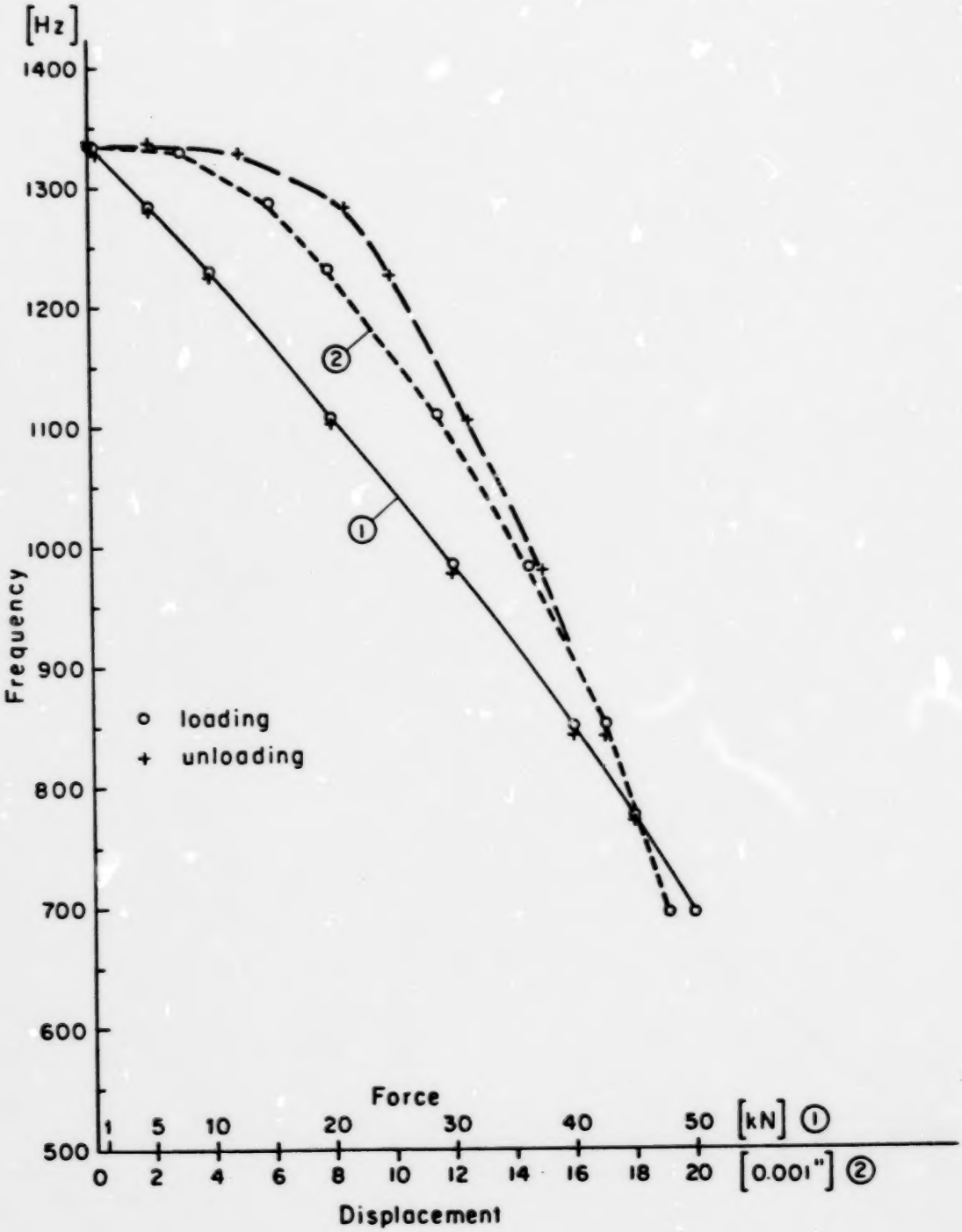

Fig. 7 - Calibration of ring 6.

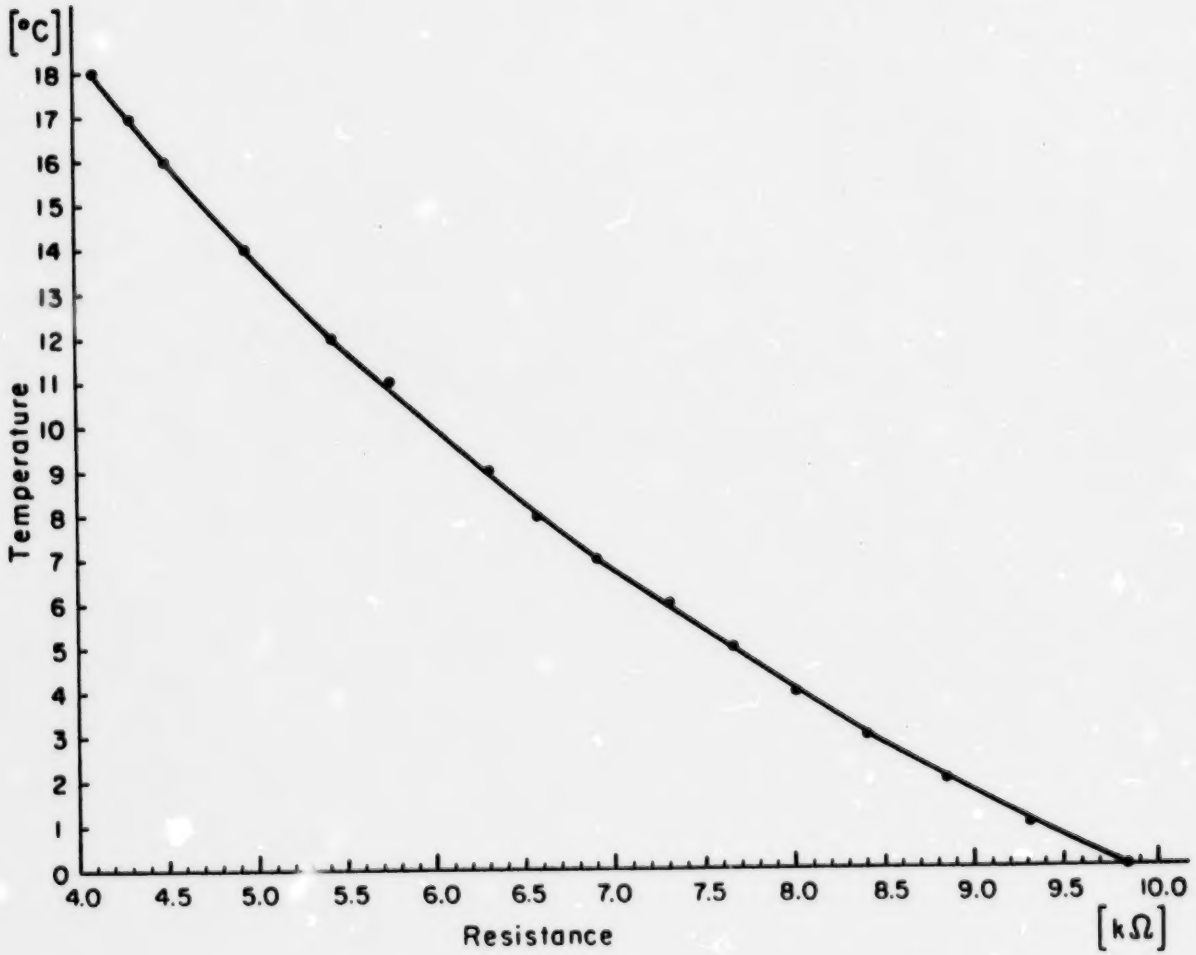

Fig. 8 - Calibration chart for thermistor in MRL strain ring.

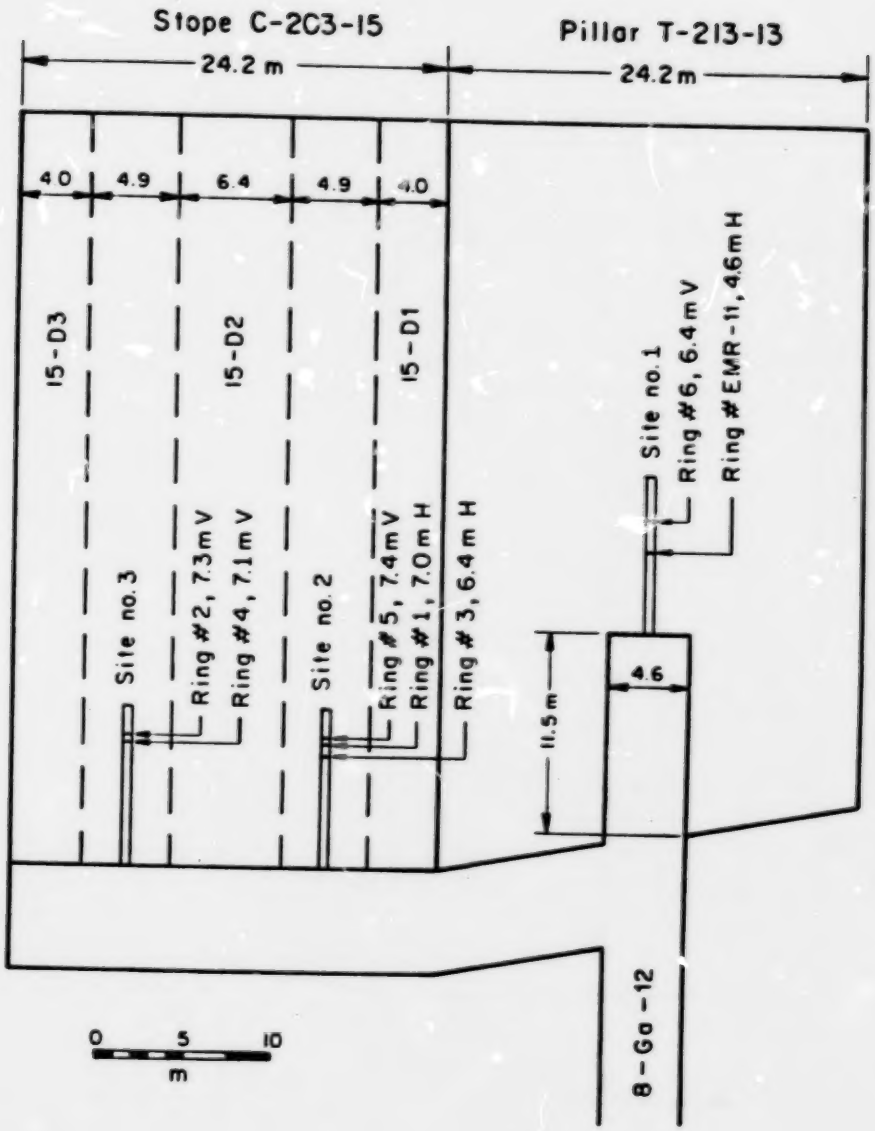

Fig. 9 Location of rings installed at Niobec Mine on 850 level

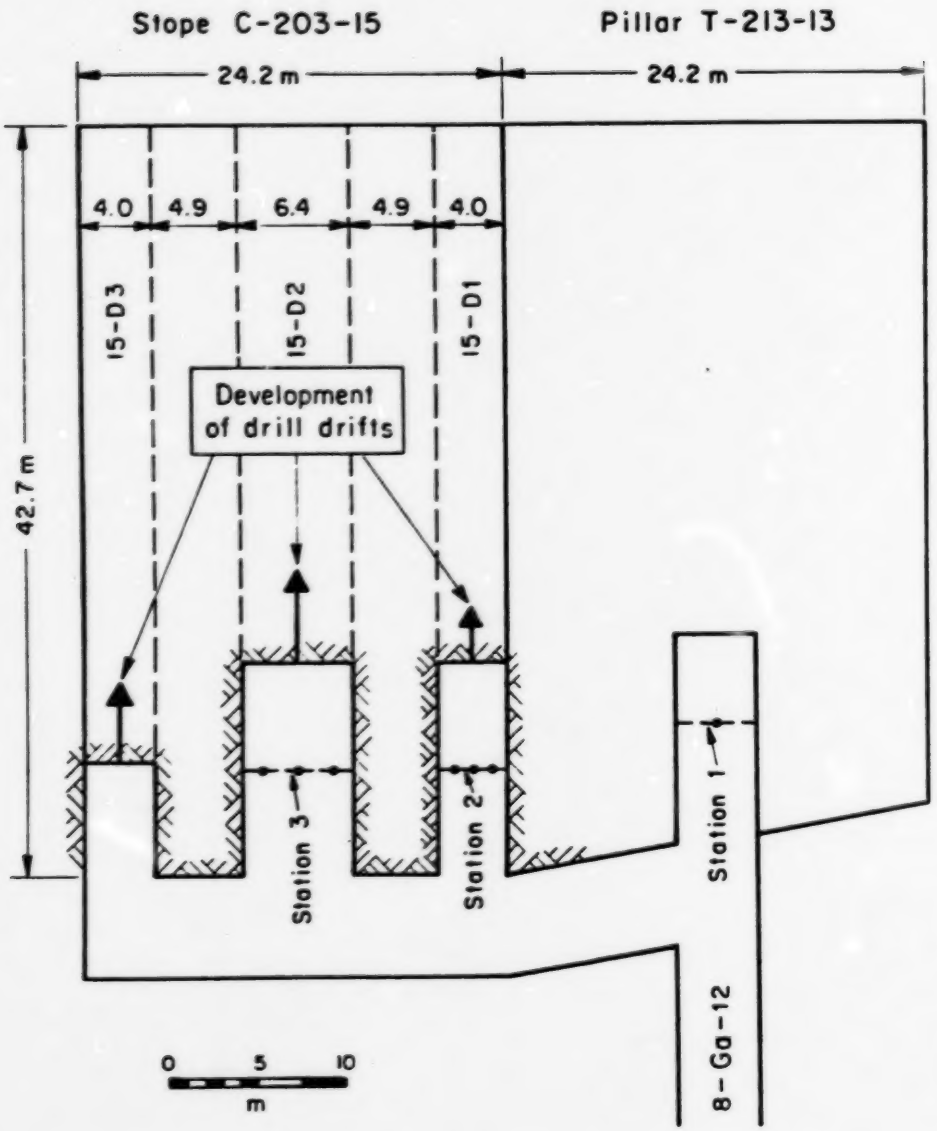

Fig. 10 - Mining geometry on November 27, 1986 at the monitoring site on 850 level.

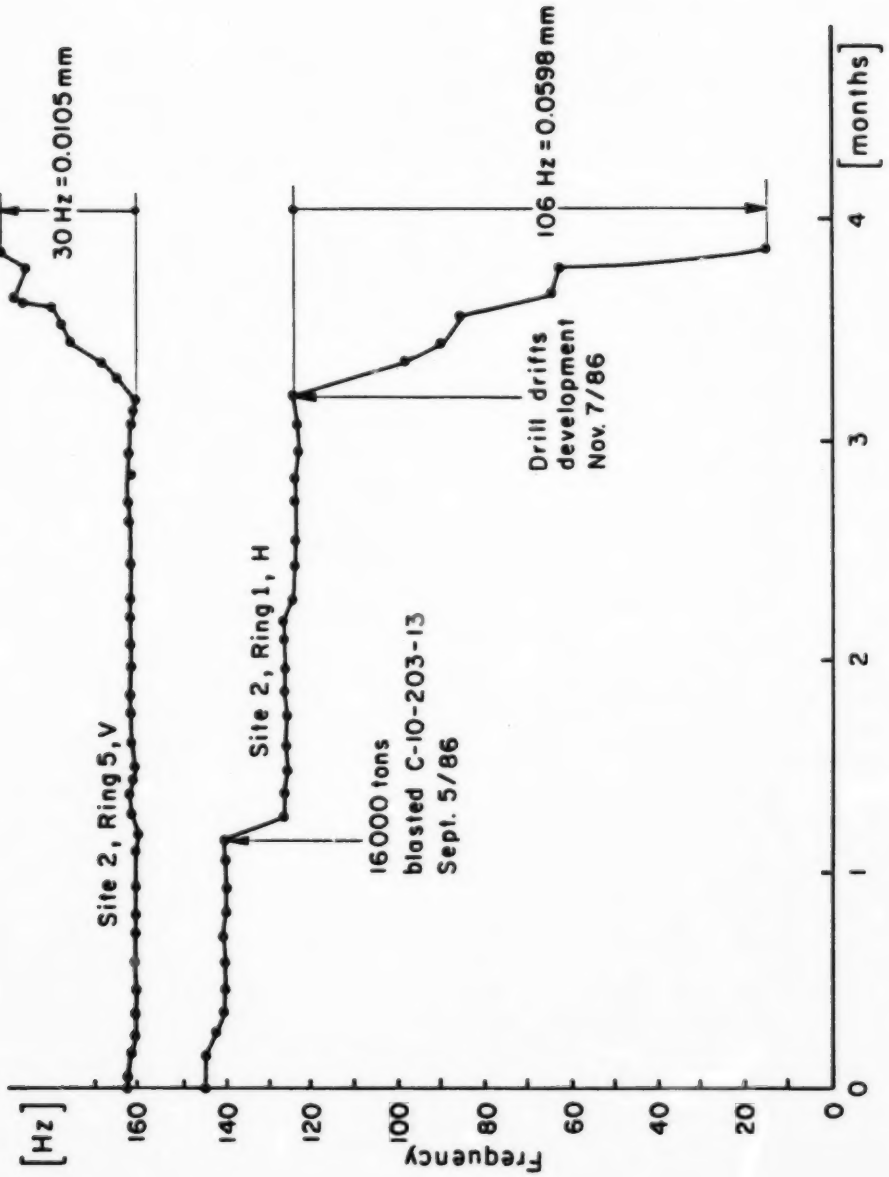

Fig. 11 - Reaction of MRL strain rings in drill drift pillar.